CLAIMS

What is claimed is:

1. A probe head for use with a spectrometer to analyze a material, the probe head comprising:

a light source arranged to irradiate a sample volume of the material proximate the probe head; and

an optical pick-up arranged to receive light emitted from the irradiated sample volume and transmit the emitted light to the spectrometer,

wherein the sample volume is disposed at least partially circumferentially around the light source.

2. The probe head of claim 1, further comprising a shaft having a longitudinal axis and housing the light source and the optical pick-up.

3. The probe head of claim 2, further comprising a reflector positioned within the shaft and having a first reflective surface for reflecting light from the light source through a wall of the shaft and into the sample volume to irradiate the sample volume.

4 The probe head of claim 3, wherein the reflector includes a second reflective surface for reflecting light emitted from the sample to the optical pick-up.

5. The probe head of claim 4, wherein the first reflective surface and the second reflective surface are each generally linear in shape.

6. The probe head of claim 4, wherein the first reflective surface and the second reflective surface are each generally elliptical in shape.

7. The probe head of claim 4, wherein the shaft includes:

a first window formed in the walls of the shaft for transmitting light reflected from the first reflective surface into the sample volume, and

a second window formed in the walls of the shaft for transmitting light emitted from the sample volume to the second reflective surface.

8. The probe head of claim 7, wherein the first window and the second window are generally annular in shape.

9. The probe head of claim 8, wherein the first window and the second window are each selectively transmissive about their circumferences.

10. The probe head of claim 4, wherein the first reflective surface is oriented to reflect at least a portion of the light from the light source in a direction generally perpendicular to the longitudinal axis of the shaft.

11. A probe head for use with a spectrometer to analyze a material, the probe head comprising:

a shaft extending along a longitudinal axis;

a light source arranged within the shaft;

a reflector arranged within the shaft a longitudinal distance from the light source to reflect at least a portion of the light from the light source in a direction generally perpendicular to the longitudinal axis of the shaft to irradiate a sample volume of the material proximate the probe head; and

an optical pick-up arranged within the shaft to receive light emitted from the irradiated sample volume and transmit the received light to the spectrometer.

12. The probe head of claim 11, wherein the reflector includes a passage for permitting light from the light source to be directly received by the optical pick-up.

13. The probe head of claim 12, wherein the passage is an optical fiber.

14. The probe head of claim 13, wherein the passage is an open tube formed in the reflector.

15. The probe head of claim 14, further comprising a first shutter for selectively blocking the passage.

16. The probe head of claim 11, further comprising an optical blocking element positioned in the optical path between the light source and the optical pick-up to force the optical path into the sample material.

17. The probe head of claim 11, further comprising a shutter for selectively blocking light emitted from the sample volume from reaching the optical pick-up to facilitate calibration of the spectrometer.

18. A method of spectroscopically analyzing a material comprising:

inserting a probe head of a spectrometer into the material along an insertion axis, the probe head emitting light at least generally perpendicular to the insertion axis,

moving the probe head along the insertion axis within the material to irradiate, with the probe head, a sample volume of the material, the sample volume extending at least partially about the circumference of the probe head, and

analyzing light reflected from the sample volume of material.

19. A probe head for use with a spectrometer to analyze a flowing material, the probe head comprising:

a light source arranged to irradiate a sample volume of the flowing material proximate the probe head;

an optical pick-up arranged to receive light emitted from the irradiated sample volume; and

a planing element shaped to cause the probe head to skim the surface of the flowing material when in contact with the flowing material.

20. The probe head of claim 19, wherein the planing element has a convex surface for contacting the flowing material.

21. The probe head of claim 20, further comprising a constant force generator for applying a constant force to the probe head to maintain the planing element in contact with the surface of the flowing material.

22. The probe head of claim 21, wherein the constant force generator is a spring, or a pneumatic element.

23. A probe assembly for use with a spectrometer to analyze a flowing material, the probe head comprising:

a housing, having arranged therein, two or more probe heads for use with a spectrometer, wherein each of the probe heads are simultaneously able to irradiate and collect spectral information on the flowing material, and include

(a) a light source arranged to irradiate a sample volume of the flowing material proximate the probe head, and

(b) an optical pick-up arranged to receive light emitted from the irradiated sample volume;

wherein the housing is shaped for disposal of the probe assembly in the path of the flowing material.

24. The probe assembly of claim 23, wherein the housing is aerodynamically shaped to minimize turbulence of the flowing material within the sample volume.

25. The probe assembly of claim 24, wherein the housing is shaped like an air foil having a leading edge, the leading edge being oriented to face the flowing material.

26. The probe assembly of claim 23, wherein the probe heads are arranged along a common axis within the housing.

27. The probe assembly of claim 23, wherein the probe heads are arranged along two or more common axes to create a two-dimensional array of probe heads.

28. The probe assembly of claim 23, wherein each optical pick-up is connected by way of a common optical fiber element to the spectrometer.

29. A probe head for use with a spectrometer to analyze a material, the probe head comprising:

a light source arranged to irradiate a sample volume of the material proximate the probe head;

an optical pick-up arranged to receive light emitted from the irradiated sample volume and transmit the emitted light to the spectrometer for analysis;

an optical blocking element positioned in the optical path between the light source and the optical pick-up to force the optical path into the sample volume, and

a reference shutter for selectively blocking light emitted from the irradiated sample volume from reaching the optical pick-up to facilitate calibration of the spectrometer.

30. The probe head of claim 29, further comprising a housing having a sample window proximate the sample volume, the light source irradiating the sample volume through the sample window, the sample window transmitting light emitted from the sample volume to the optical pick-up.

31. The probe head of claim 30, wherein the optical blocking element is biased into contact with the sample window.

32. The probe head of claim 31, wherein the optical blocking element is opaque.

33. The probe head of claim 31, wherein the reference shutter is movable between a closed position that blocks light emitted from the sample volume from reaching the optical pick-up and an open position that permits light emitted from the sample volume to reach the optical pick up.

34. The probe head of claim 33, wherein movement of the reference shutter from the open position to the closed position causes the optical blocking element to move out of contact with the sample window.

35. The probe head of claim 29, wherein the reference shutter includes a reference surface having a uniform reflectance value to facilitate calibration of the spectrometer.

36. A method of spectroscopically analyzing a material comprising:

irradiating a sample volume of the material with light from a light source,

transmitting light emitted from the irradiated sample volume to an optical pick up that is optically connected to a spectrometer,

forcing an optical path between the light source and the optical pick-up into the sample volume; and

selectively blocking light emitted from the irradiated sample volume from reaching the optical pick-up to facilitate calibration of the spectrometer.

37. The method of claim 36, wherein the step of forcing the optical path includes blocking light reflected from a sample window within the optical path from reaching the optical pick-up.

38. The method of claim 36, wherein the step of selectively blocking light includes selectively moving a reference shutter into the optical path to block light emitted from the irradiated sample volume from reaching the optical pick-up.